

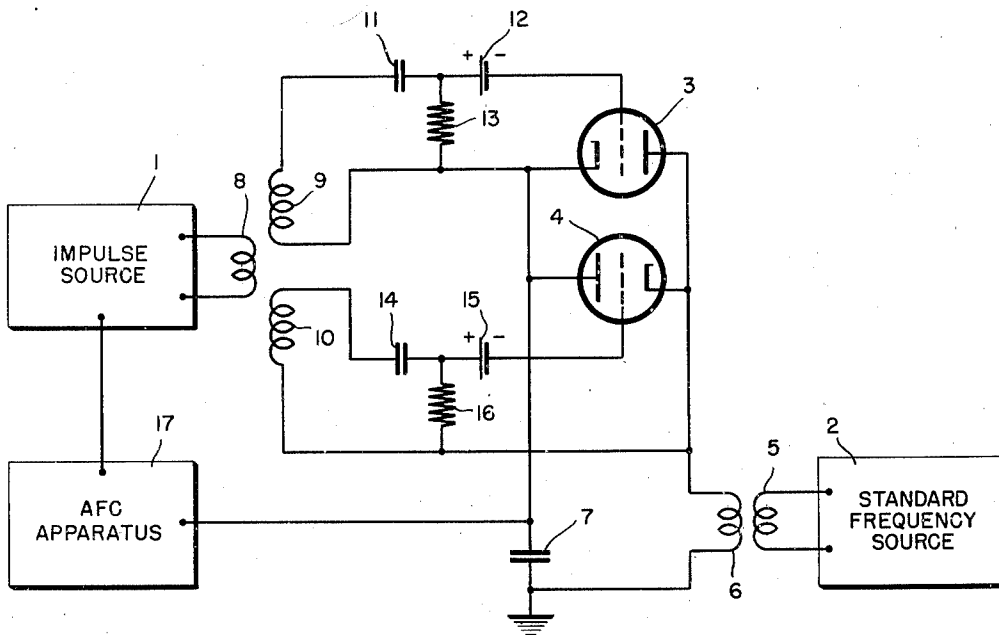
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PHASE COMPARATOR CIRCUIT

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PHASE COMPARATOR CIRCUIT

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This invention relates to frequency control apparatus and particularly to apparatus of this character, wherein the phase relationship between a series of impulses and a source of standard frequency is compared for the purpose of developing control signals to correct the frequency of the impulse source.

In many cases, particularly in television systems, it is desired to maintain a relatively constant frequency of a series of impulses and/or periodic waves. Impulsive energy is employed for numerous purposes in television systems. For example, it is conventional to transmit as a part of a composite television signal, a series of impulses for system control purposes, such as for synchronizing the transmitting apparatus with the receiving apparatus. Also, in some instances, a series of impulses is used for the production of a saw tooth wave. In any case it is customary to derive the impulses at some frequency which is either fundamentally or harmonically related to a source of standard frequency. For this purpose, it is convenient to employ a commercial source of substantially sinusoidal alternating current having a frequency of 60 cycles per second as the standard frequency source.

In order that the oscillator or other source of impulses be maintained in a predetermined frequency relationship to a source of standard frequency, it is necessary to frequently compare the frequency of the oscillator or of the generated impulses with the wave derived from the standard frequency source. Any deviations from the predetermined relationship are detected by the phase comparison apparatus for the development of suitable control signals to alter the frequency of the impulse generator. Most of the phase comparison devices employed previously have operated in such a manner that the impulses are compared with the standard frequency wave no more than once during each cycle of the standard frequency wave. In general, devices of this character compare the impulses during either the positive or negative half cycles of the standard frequency wave. As a result, the phase relationship of the impulses and the standard frequency wave may vary substantially all the way from 0 to 360°. In the case where a phase variation approaching 360° occurs, either a relatively large correcting signal must be developed or a considerable number of correcting signals of smaller magnitude must be developed. In the first case, there is a distinct tendency for the apparatus to hunt. In the second case, the desired frequency correction requires a considerable time to be effected.

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It, therefore, is an object of the present invention to provide a novel frequency control apparatus, whereby a closer relationship between the frequency of a periodic wave and a source of standard frequency may be effected than has heretofore been accomplished.

Another object of the invention is to provide a novel phase comparison apparatus whereby a comparison may be effected between a series of impulses and a standard frequency wave more than once during each cycle of the standard frequency wave.

In accordance with the present invention, there is provided a frequency control system having a phase comparison apparatus comprising an energy storage circuit which is responsive to the phase relationship between a periodic wave, such as a series of impulses, and a source of standard frequency. The apparatus also comprises a pair of grid-controlled vacuum tubes having the space discharge paths thereof coupled to the energy storage circuit. These tubes may be connected respectively in opposite polarity between the standard frequency source and the energy storage circuit in one form of the invention so that the space current for the tubes is derived from the standard frequency source. The tubes, thus, function as a full wave electronic switch operating on alternate half cycles of the standard frequency wave. The control grid circuits of the tubes are coupled in like polarity to a source of impulses, the frequency of which is to be compared with the source of standard frequency. The tubes are each rendered conducting simultaneously, concurrently with the occurrence of each of the series of impulses. Depending upon the polarity of the standard frequency wave at the instant when the tubes are rendered conducting, the energy storage circuit is supplied with energy of a polarity and magnitude representative of the instantaneous polarity and magnitude of the standard frequency source. The energy with which the storage circuit is provided is utilized to control the frequency of the impulse generator by means of conventional automatic frequency control apparatus.

For a better understanding of the invention, together with other and further objects thereof, reference is made to the following description, taken in connection with the accompanying drawing and its scope will be pointed out in the appended claims.

The single figure of the accompanying drawing is a schematic diagram of apparatus embodying the invention in an illustrative form.

Referring now particularly to the drawing, the apparatus includes an impulse source 1. This source may be entirely conventional for the purpose of developing a series of unidirectional impulses occurring at a predetermined frequency which is related either fundamentally or at least harmonically to a 60 cycle standard frequency. A source of standard frequency 2 also is provided. This source may be a commercial power supply from which may be derived a substantially sinusoidal wave having a frequency of 60 cycles per second.

The phase comparison apparatus includes a pair of grid-controlled rectifiers, such as triodes 3 and 4. If desired, a twin triode amplifier, such as an RCA type 6SN7 may be employed as the two rectifier tubes. Space current for the tubes is derived from the source of standard frequency which is connected to a primary winding 5, inductively coupled to a secondary winding 6. The secondary winding 6 is connected between ground and one space discharge tube electrode of each of the tubes 3 and 4. In the case of the tube 3, the winding 6 is connected to the anode, and in the case of the tube 4, it is connected to the cathode. By reason of this circuit arrangement the tubes act as a full wave electronic switch capable of being conditioned for operation on alternate half cycles of the standard frequency wave. The space discharge circuit of the tubes 3 and 4 also is coupled to an energy storage circuit, such as the circuit including a condenser 7. The cathode of the tube 3 and the anode of the tube 4 are each coupled to one terminal of the condenser and the other terminal of this condenser is grounded.

The conductivity of the rectifier tubes 3 and 4 is controlled by the impulses derived from the source 1. For this purpose the impulse source is connected to a coil 8. Two other coils 9 and 10 are inductively coupled, in the polarity shown, to the coil 8. The upper terminal of the coil 9 is coupled by a condenser 11 in series with a negative biasing voltage source, such as a battery 12 to the control grid of the tube 3. The lower terminal of the coil 9 is connected to the cathode of the tube 3. A leak resistor 13 is provided for the coupling condenser 11. The upper terminal of the coil 10 similarly is coupled by a condenser 14 in series with a negative biasing battery 15 to the control grid of the tube 4, and the lower terminal of this coil is connected to the cathode of this tube. A leak resistor 16 is provided for the coupling condenser 14.

Finally, the ungrounded terminal of the condenser 7 is coupled to automatic frequency control apparatus 17. This apparatus may be conventional and many devices of this character are well known to those versed in the art. The automatic frequency control apparatus is coupled, as indicated, to the impulse source 1, also, in a manner well known in the art, whereby to alter the frequency of the impulse source, in accordance with the voltages developed in the storage condenser 7.

Referring now to the operation of the apparatus, assume that one of the impulses derived from the source 1 occurs at substantially the same time as the wave derived from the standard frequency source 2 reaches the peak of a positive half cycle. Prior to the occurrence of the impulse both of the rectifier tubes 3 and 4 are maintained substantially nonconducting by reason of the connections of the biasing batteries 15 to the respective grids. It is assumed that the

impulses derived from the source 1 induces impulses in the coils 9 and 10 of such a character to render the upper coil terminals positive relative to the lower coil terminals. Also, it is to be understood that the magnitudes of the impulsive voltages induced in the coils 9 and 10 are sufficient to overcome the negative biasing of the control grids of the rectifier tubes. Consequently, when an impulse is impressed upon the control grids of these tubes they are both conditioned for conduction. In the assumed case, however, current will flow only through the tube 3 because of the polarity of its connection to the coil 6 wherein a voltage, which is positive, relative to ground, is induced. As a result of the conduction of space current in the tube 3, the condenser 7 is charged in a representative polarity and to a magnitude representative of the instantaneous value of the standard frequency wave. In the assumed case, the condenser will receive a maximum positive charge since the standard frequency wave is at a positive peak.

If it is further assumed that the desired phase relationship between the source of impulses and the standard frequency source is one wherein the impulses occur at nodal points of the standard frequency wave, it is seen that the described phase relationship deviates 90° from the desired one. Consequently, a maximum correcting voltage developed in the manner described across the condenser 7 is impressed upon the automatic frequency control apparatus 17 for applying a maximum correcting voltage to the impulse source 1.

Should the occurrence of one of the impulses coincide with a negative half cycle of the standard frequency wave, space current will be conducted in the rectifier tube 4 whereby to oppositely charge the condenser 7. The magnitude of the space current and consequently, the charge imparted to the condenser, depends upon the instantaneous magnitude of the standard frequency wave. The automatic frequency control apparatus 17 functions as before in response to the charge accumulated by the condenser 7 to apply a suitable correcting voltage to the impulse source 1. In this case, the correction applied will be in a sense opposite to that described previously.

It may be seen from the foregoing description of an illustrative embodiment of the invention that there can be maintained a close relationship between the frequency of the impulses derived from the source 1 and the frequency of the wave derived from the standard frequency source 2. This beneficial result is obtained by the novel use of what, in effect, is a full wave electronic switch connection of the tubes 3 and 4 which is capable of functioning on alternate half cycles of the standard frequency wave. Also, an important feature of the present invention is the facility provided for simultaneously rendering the tubes effective only during the occurrence of one of the series of impulses. In this manner the charge on the condenser 7 is at all times representative of the phase relationship between the impulse source and the standard frequency source.

While there has been described what, at present, is considered the preferred embodiment of the invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it, therefore, is aimed in the appended claims to cover all such changes and

modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. Frequency control apparatus comprising, a source of impulses, a source of a standard frequency wave, a condenser, a pair of vacuum tubes connected respectively in opposite polarity between said standard frequency wave source and said condenser, means for separately biasing said tubes so as to be normally non-conducting, means including said source of impulses to periodically condition both of said tubes simultaneously for conduction of space current derived from said standard frequency wave source to charge said condenser in polarity and magnitude dependent upon the instantaneous polarity and magnitude of said standard frequency wave, and automatic frequency control apparatus coupled between said condenser and said impulse source to control the frequency of said impulses in accordance with the charge of said condenser.

2. Frequency control apparatus comprising, a source of impulses, a source of a standard frequency wave, an energy storage condenser, a pair of vacuum tubes connected respectively in opposite polarity between said standard frequency wave source and said condenser, individual biasing means coupled to said tubes so as to render them normally non-conducting, means coupled to said source of impulses to periodically condition both of said tubes simultaneously for conduction of space current derived from said standard frequency wave source to charge said storage condenser in polarity and magnitude dependent upon the instantaneous polarity and magnitude of said standard frequency wave, and automatic frequency control apparatus coupled between said storage condenser and said impulse source to control the frequency of said impulses in accordance with the charge of said condenser.

3. Frequency control apparatus comprising, a source of impulses, a source of a standard frequency wave, an energy storage condenser, a pair of vacuum tubes connected respectively in opposite polarity between said standard frequency wave source and said condenser, individual sources of biasing voltage coupled respectively to said tubes to render them normally non-conducting, individual couplings between said tubes and said source of impulses, whereby said impulses are effective to periodically condition both of said tubes simultaneously for conduction of space current derived from said standard frequency wave source to charge said storage condenser in polarity and magnitude dependent upon the instantaneous polarity and magnitude of said standard frequency wave, and automatic frequency control apparatus coupled between said storage condenser and said impulse source to control the frequency of said impulses in accordance with the charge of said condenser.

4. Frequency control apparatus comprising, a source of impulses, a source of a sinusoidal wave of standard frequency, an energy storage condenser, a pair of grid-controlled vacuum tubes coupled respectively in opposite polarity between said sinusoidal wave source and said condenser, two sources of unidirectional energy connected respectively between the control grids and associated cathodes of said tubes so as to render said tubes normally non-conducting, couplings including a pair of coils between the respective control grids of said tubes and said source of impulses, whereby said impulses are effective to periodically condition both of said tubes simultaneously for conduction of space current derived from said sinusoidal wave source to charge said storage condenser in polarity and magnitude dependent upon the instantaneous polarity and magnitude of said sinusoidal wave, and automatic frequency control apparatus coupled between said storage condenser and said impulse source to control the frequency of said impulses in accordance with the charge of said condenser.

5. Frequency control apparatus comprising, a source of impulses of positive polarity, a source of a sinusoidal wave of standard frequency, an energy storage condenser, a pair of grid-controlled vacuum tubes coupled respectively in opposite polarity between said sinusoidal wave source and said condenser, two sources of unidirectional energy of substantially equal voltage having their negative terminals connected respectively to the control grids of said tubes and their positive terminals connected respectively to the cathodes of said tubes, whereby to render said tubes normally non-conducting, individual inductive couplings between the respective control grids of said tubes and said source of impulses, whereby said impulses are effective to periodically condition both of said tubes simultaneously for conduction of space current derived from said sinusoidal wave source to charge said storage condenser in polarity and magnitude dependent upon the instantaneous polarity and magnitude of said sinusoidal wave, and automatic frequency control apparatus coupled between said storage condenser and said impulse source to control the frequency of said impulses in accordance with the charge of said condenser.

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